Off-pump coronary artery bypass grafting is a safe and effective treatment modality for Asian patients requiring coronary revascularisation

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ABSTRACT

Introduction: Off-pump coronary artery bypass grafting (OPCABG) is gaining widespread acceptance as the preferred choice for myocardial revascularisation. However, no definite data exist as to whether it is better than conventional CABG. We aimed to study the efficacy of the procedure in our patients, which constituted of a predominantly Asian population.

Methods: Between January 2000 and December 2002, 1062 patients underwent isolated coronary artery bypass in our institution. 184 patients (17.3 percent) underwent OPCABG. Patients were preoperatively prospectively risk stratified under the EuroSCORE risk assessment model under high, medium and low risk classes thereby making them comparable. Post-operative complications, intensive care unit stay, hospital stay, types of grafts done were then analysed in these different risk classes.

Results: The incidence of off-pump procedures showed a gradual increase over the last three years in this institution. A reduction in the number of post-operative complications, hospital stay, intensive care unit stay and mortality in the off-pump group was observed. Certain differences were found to be statistically significant.

Conclusion: Off-pump CABG is a safe and viable alternative to conventional CABG as a treatment modality for surgical coronary revascularisation.

Keywords: cardiac disease, coronary artery bypass grafting, myocardial revascularisation, off-pump coronary artery bypass, grafting

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INTRODUCTION

Coronary artery bypass graft (CABG) surgery is a highly successful method for myocardial revascularisation required in the treatment of ischaemic heart disease. Conventional CABG involves rerouting the patient's blood through the heart-lung machine (cardio-pulmonary bypass or CPB), followed by the stoppage of the heart (i.e. cardioplegia). Conventional CABG has been observed to have ill-effects due to CPB-related post-operative morbidity and mortality[1-8].

Off-pump CABG (OPCABG) is a relatively new technique that is being increasingly adopted in various institutions. OPCAB is a form of open-heart surgery in which patients with clogged arteries are bypassed while the heart is still beating. OPCAB eliminates the use of the CPB and cardioplegia. Thus, theoretically, it should bring about significant differences with regard to post-operative morbidity and mortality, compared to patients undergoing conventional CABG. Many clinical studies performed have, to various extents, established the effectiveness of OPCAB. Landmark studies have indicated that patients undergoing OPCABG have benefited in ways that include shorter post-operative hospital stays[1,2], fewer pulmonary complications[1,2], lesser need for blood transfusions[1-3], fewer post-operative cardiac arrhythmias[1], fewer incidences of intra- or post-operative myocardial infarctions[1], and neurological dysfunction[1,3-6]. It has been established that some of these differences in outcomes are significant in specific subgroups of patients classified according to their pre-operative risk assessment[7,8].

However, few studies actually take into account the effectiveness of this procedure on Asian patients. It is now well accepted that there exist inherent differences between Asian and European patients with regard to differences in the size of target coronary vessels. Thus, this study aims to understand the development and effectiveness of the OPCAB procedure as a treatment modality for coronary revascularisation in this institution, whose vast majority of patients are Asian. Where necessary, statistical comparisons have been made between this innovative procedure (i.e. OPCAB) and conventional CABG to better understand the effectiveness of this procedure.

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METHODS

From January 2000 to December 2002, 1062 patients underwent isolated coronary bypass surgery. 184 patients (17.3%) underwent bypass surgery without the CPB machine (i.e. OPCAB). Patients who underwent combined procedures were excluded. Seven patients who had their initial grafts done off- pump, and were converted to on-pump for the remaining grafts, were included in the OPCAB group with an intention to treat approach (Table I).

Table I. Number of procedures performed between the period of Jan 2000 and Dec 2002 inclusive.

	2000	2001	2002	Total CAB procedures
Conventional CABG procedures performed	201	239	438	878
OPCAB procedures performed	46	39	99	184
Total	247	278	537	1062

Risk stratification

All patients who underwent CABG were prospectively risk stratified pre-operatively. They were risk stratified utilising three separate and independent risk stratification models, namely: the Parsonnet, EuroSCORE and Northern New England. To eliminate selection bias in this study, the EuroSCORE risk stratification model, which has shown better correlation to post-operative outcomes in Asian patients[9], was utilised.

Using the calculated EuroSCORE values, the patients were thus classified into high, moderate and low risk groups (Table II):

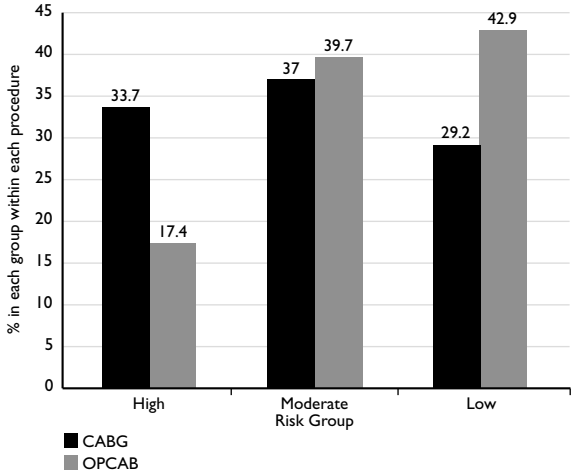
i. Low risk group (EuroSCORE value ≤2)
ii. Moderate risk group (2<EuroSCORE value <6)
iii. High risk group (EuroSCORE value ≥6)

Table II. Classification and numbers under EuroSCORE risk groups.

	High risk	Moderate risk	Low risk	Total
CABG	294 (33.7%)	326 (37.0%)	258 (29.2%)	878
OPCAB	**32 (17.4%)**	**73 (39.7%)**	**79 (42.9%)**	**184**
Total	326 (31.1%)	399 (37.5%)	337 (31.4%)	1062

Thus, greater number of patients who underwent conventional CABG were classified as high risk compared to those who underwent OPCAB (33.7% vs 17.4%). OPCAB procedure had a greater proportion of moderate and low risk patients

Fig. 1 Distribution among risk groups.



compared to conventional CABG (39.7% and 42.9% vs. 37.0% and 29.2%, respectively) (Fig. 1).

The mean EuroSCORE values of the patients in the respective risk groups were also calculated. The mean EuroSCORE value was indicative of the overall expected mortality within the respective risk groups or the patient population on the whole. In general, OPCAB patients were lower risk scored. Moreover, after stratification, the patients from both procedures were comparable (Table III).

Table III. Mean EuroSCORE values within respective risk groups.

	CABG	**OPCAB**	p-value
Low risk	1.25 ± .788	**1.20 ± .734**	0.648
Moderate risk	3.95 ± .849	**3.78 ± .813**	0.127
High risk	8.27 ± 2.88	**8.31 ± 3.21**	0.940
All patients	4.61 ± 3.35	**3.48 ± 2.93**	<0.001

Data collection

In our study, data was collected by the Singapore Cardiac Database, which is sponsored by the Ministry of Health. The outcomes of the patients who had been through the OPCAB procedure were looked into and where possible, comparisons were made with respect to outcomes from the conventional CABG patient group. Factors looked at were considered to be good predictors of post-operative morbidity. Data on the duration of post-operative intensive care unit (ICU) stay and hospital stay were also analysed. Furthermore, total number of grafts performed and the type of grafts used, be it arterial or venous, were also considered. Additionally, post-operative complications were looked at (Table IV).

The preoperative, risk classification and post-operative data of the patients in this study was

Table IV: Complications and classification.

Category of complications	Types of complications
1. Operative	a. re-operative bleeding
2. Infections	a. pneumonia b. sternal wound infection c. leg wound infection d. pyrexia
3. Pulmonary	a. pulmonary oedema b. pleural effusion c. pneumothorax
4. Neuronal	a. neuropraxia b. temporary/permanent stroke c. delirium
5. Renal	a. renal failure b. renal impairment c. dialysis d. urinary retention
6. Vascular	a. limb ischaemia b. femoral dissection
7. Other	a. cardiac arrhythmias • atrial flutter • atrial fibrillation • bradycardia b. post-operative myocardial infarction

taken from the Perfusion Department's database. Patients were followed for a period of 30 days after the procedure. Mortality was taken into account if it occurred within 30 days following the procedure. The data collection and subsequent statistical analysis was performed with MS Excel for Windows and SPSS for Windows. Statistical tests of significance were performed and a p-value <0.05 was assumed to be statistically significant.

Surgical technique and procedure

Conventional CABG (on pump)

Seven different surgeons performed the conventional CABG operations. All operations were performed through a median sternotomy. Standard techniques of CPB were used. Both antegrade and retrograde blood cardioplegia cannulas were placed. The aorta was cross-clamped, the distal anastomoses were first performed, followed by the proximal anastomoses. Full heparinisation was used. Heparin was reversed following weaning from the CPB. The LIMA to LAD graft was used, where possible, and was constructed first.

Off-pump CABG

Three different surgeons adopted the OPCAB technique. All operations were performed through a median sternotomy. The order of grafting was the LIMA to LAD, followed by other vessel conduits. The Octopus® tissue stabiliser (Medtronic, Minneapolis, MN, USA) was used to stabilise the beating heart to perform distal anastomoses. Coronary shunts were used to maintain target vessel haemostatis.

RESULTS

The comparison of means of the duration of ICU and hospital stay between the two procedures, in all the patients as a whole regardless of their risk classes, indicate a significant difference only in the length of ICU stay and not in the length of post-operative hospital stay. There were significant differences in the numbers and types of grafts performed between the procedures (Table V). OPCAB patients had significantly lesser number of total grafts performed on them as compared to on-pump cases (2.54 ± 0.98 vs. 3.18 ± 0.80, p<0.001). Also, OPCAB patients had a greater number of arterial grafts compared to on-pump patients (1.18 ± 0.40 vs. 0.99 ± 0.40, p<0.001) and a lesser number of venous grafts than on-pump patients performed on them (1.35 ± 1.02 vs. 2.18 ± 0.93, p<0.001).

Table V. Differences between OPCAB and conventional CABG within all risk groups.

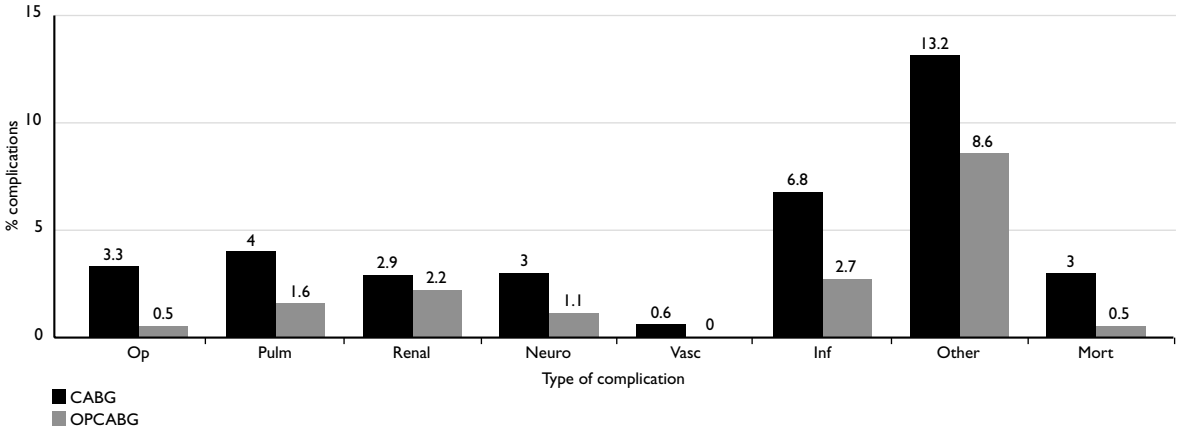
		CABG (n=878)	OPCABG (n=184)	p-value
Mean ICU stay		2.74 ± 2.32	2.31 ± 0.959	**0.02**
Mean hospital stay		6.88 ± 7.58	5.88 ± 3.84	**0.099**
Mean number of grafts	Arterial	0.99 ± 0.40 (31.1)	1.18 ± 0.40 (46.5)	**<0.001**
	Venous	2.18 ± 0.93 (68.6)	1.35 ± 1.02 (53.2)	**<0.001**
	Total	3.18 ± 0.80	2.54 ± 0.98	**<0.001**

Under individual risk groups (results not shown), the differences were similar to the table above. Patients who underwent OPCAB had less total grafts performed and a greater number of arterial conduits were used. These differences reached a level of statistical significance. The mean ICU stay and hospital stay in patients under the low, moderate and high risk groups were lower in the OPCAB patients than in the on-pump patients. However, the results did not reach a level of statistical significance.

Table VI: Complications and mortality between CABG and OPCABG patients under different risk categories.

	Low risk			Moderate risk			High risk		
	CABG (n=258)	OPCABG (n=79)	p-value	CABG (n=326)	OPCABG (n=73)	p-value	CABG (n=294)	OPCABG (n=32)	p-value
Operative complications	4 (1.6%)	0	0.371	9 (2.8%)	1 (1.4%)	0.454	15 (5.1%)	0	0.229
Pulmonary complications	4 (1.6%)	1 (1.3%)	0.699	5 (1.5%)	2 (2.7%)	0.354	25 (8.5%)	0	0.082
Renal complications	5 (1.9%)	0	0.288	7 (2.1%)	3 (4.1%)	0.247	27 (9.2%)	1 (2.9%)	0.246
Neurological complications	9 (3.5%)	2 (2.5%)	0.318	3 (0.9%)	0	0.561	14 (4.8%)	0	0253
Vascular complications	0	0	–	0	0	–	5 (1.7)	0	0.617
Infections	16 (6.2%)	2 (2.5%)	0.204	11 (3.4%)	2 (2.7%)	0.596	31 (10.5%)	1 (2.9%)	0.181
Other complications	24 (9.3%)	3 (3.8%)	0.117	26 (7.9%)	9 (12.3%)	0.135	63 (21.4%)	4 (12.5%)	0.223
Mortality	2 (0.8%)	0	0.610	1 (0.3%)	0	0.825	23 (7.8%)	1 (3.1%)	0.331

Fig. 2 Incidence of complications.



The incidence of complications in all the 1062 patients together regardless of Risk Class.

There was little difference in the way the outcomes of the two procedures differed between the three risk categories (Table VI). In all situations, the incidence of complications in the OPCAB group was less than that of the conventional CABG group with an exception only in operative complications in all of the three different risk groups. Although clinically significant, these differences did not reach a level of statistical significance. This is due to the low numbers of patients studied from the OPCAB group.

Mortality was observed to be generally lower in the OPCAB group. There was no case of mortality in patients who underwent OPCAB in the low and moderate risk groups as opposed to mortality rates of 0.8% and 0.3% in those patients from the low and moderate groups, respectively, who underwent conventional CABG with pump.

However, these differences did not reach a level of statistical significance. In the high risk group, there was lower mortality rate in the OPCAB procedure compared to the conventional CABG with pump procedure (3.1% OPCAB vs. 7.8% conventional CABG, p=0.331).

Table VII. Mortality in both procedures.

	CABG		**OPCAB**	
	Predicted	*Observed*	**Predicted**	***Observed***
Low risk	1.25 ± .788	*0.8*	**1.20 ± .734**	***0***
Moderate risk	3.95 ± .849	*0.3*	**3.78 ± .813**	***0***
High risk	8.27 ± 2.88	*7.8*	**8.31 ± 3.21**	***3.1***
All patients	4.61 ± 3.35	*3.0*	**3.48 ± 2.93**	***0.5***

The observed mortality in all risk groups and in both procedures was always lower than the predicted mortality (Table VII).

DISCUSSION

In this institution, the first minimally invasive direct coronary artery bypass (MIDCAB) was performed in November 1995. The initial off-pump cases were performed through a minimally-invasive approach. Our early cases mostly involved single vessel grafts. From 1999 onwards, most cases were performed through a median sternotomy approach, and increasingly, most procedures involved multi-vessel grafts.

In conventional CABG, the use of the CPB machine haemodilution and anticoagulation. These result in coagulopathies, activation of the haemostatic system, and a myriad of other clinical sequelae. Clinically adverse effects include lowered intravascular colloidal oncotic pressure, release of vasoactive substances into plasma and platelet damage. Cardiopulmonary bypass also causes systemic inflammation through the activation of blood constituents. The vasoactive substances, enzymes, and microemboli produced by activation of these protein systems and cells are the cause of morbidity associated with CPB. The activation of platelets reduces platelet numbers and this causes increased postoperative bleeding times[10].

Organ damage is also a possibility due to use of CPB. Postoperative neuronal damage can result from cerebral hypoxia, but is more often due to microembolism. Renal function is depressed during CPB time due to reduced flow rate, decreased blood pressure and continuous instead of pulsatile pumping. Since renal arterial pressure is reduced, there is reduced urine output as well. If bypass duration is extremely long, renal complications are common. There is also a possibility of hepatic congestion and alteration of hepatic function following bypass[10]. The interaction between these processes and cascades, and their contribution to end organ injury are complex. This morbidity and mortality presumably arising from the CPB may possibly be avoided, if the use of the CPB is abandoned by the OPCAB procedure.

Among some of the concerns viewed of the OPCAB procedure, the number and type of grafts performed, as well as their short- and long-term patency, has been of particular interest. In many published series, OPCAB patients had a lesser number of total constructed grafts[11]. This holds true with our series as well. It can be observed that within all risk groups, OPCAB patients had a lesser number of total grafts performed and this has proven to be of statistical significance. In all risk groups, OPCAB patients had a greater proportion of their total grafts being arterial grafts. These results have raised considerable enquiry into matters such as the difficulty of the OPCAB procedure being a reason for performing a lesser number of grafts. Many studies have questioned the patency of grafts performed in the OPCAB procedure[11]. Upon studying the immediate post-operative angiographies of OPCAB patients, Lund et al reported that 97% of the OPCAB grafts were patent[11]. However, there is little literature with regard to long term patency of grafts performed in the OPCAB procedure.

The adoption rates of the OPCAB procedures also varied considerably among various institutions. In this institution, as in others, the OPCAB procedure has been adopted by only a small group of surgeons. Only three out of the six surgeons who performed CABG procedures had attempted the off-pump technique. Moreover, out of the three who had adopted this technique, only one surgeon had a significant adoption rate of 41.9%. The decision to do an off-pump procedure is up to the individual surgeon's discretion. Surgeons who had already adopted this technique were more inclined to use it where possible[2].

One of the downsides of the OPCAB technique is its relatively steep learning curve[12]. Performing anastomoses in a neither still nor bloodless field is a challenge. However, advances in exposure and stabilisation techniques have made OPCAB safe and easy to teach. Caputo et al reported that the procedure with these new advances can safely be taught to new cardiothoracic surgical trainees[12]. This has also raised considerable enquiry as to whether the

improved outcomes observed with beating-heart surgery (i.e. OPCAB) arise from more experienced surgeons with better established outcomes preferentially adopting beating-heart surgery or whether it was due to the intrinsic merits of the beating-heart technique.

The devastating neurological outcomes associated with conventional CABG with CPB, has always been a matter of concern. The reported incidence of neurological complications after conventional CABG is 3% to 7%[5]. Trehan et al reported that only 0.14% patients undergoing OPCAB demonstrated neurological complications such as stroke[6]. They found that the OPCAB technique significantly reduces the incidence of stroke after CABG especially in high risk group of patients. In our series, a trend can be noticed in that there were lesser incidences of neurological complications in the OPCAB group within all three risk groups, but they did not reach levels of statistical significance.

A study that recently investigated relationships between observed mortality and the EuroSCORE demonstrated that with increasing risk according to the EuroSCORE, the difference between predicted and observed mortality increased[8]. This holds true for the results in our series. It can be seen that in our series we have similar findings in that the difference between the predicted and observed mortality decreases and the pre-operative calculated EuroSCORE risk increases. This shows that with regard to mortality, the OPCAB procedure may have better outcomes in the high risk group.

In our series, there was only 3.1% mortality in the OPCAB high risk group, compared to 7.8% mortality in the CABG with pump high risk group. In the low and moderate risk groups, there was no mortality at all in the OPCAB group. OPCAB is therefore a very safe procedure when low and moderate risk patients are involved.

Other studies have claimed finding, to levels of statistical significance, that the OPCAB procedure indeed produces better outcomes in high risk subgroups[7]. Other significant results have also been reported in terms of ICU and hospital stay being notably reduced in the OPCAB group. In our series, a general trend was observed in all risk sub-groups having shorter post-operative ICU and hospital stay within the OPCAB procedure. However, these results did not reach a level of statistical significance.

In conclusion, our study showed that there is a general trend in the reduction of post-operative morbidity and mortality in the OPCAB procedure, compared to the conventional CABG with pump procedure. This trend can be observed along all risk groups. Our series demonstrates that the OPCAB procedure is a safe and effective procedure that can be employed on Asian patients.

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